

U.S. Environmental Protection Agency Evaluation of Uranium Mining TENORM Wastes—Characteristics, Occurrence, and Risks

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ABSTRACT

The U.S. Environmental Protection Agency is completing a multiyear effort to issue technical reports and obtain stakeholder views on future programs to mitigate potential hazards associated with uranium mining Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)¹. The technical reports are the most comprehensive issued by the Agency on this topic, and should have utility for reclamation of abandoned uranium mines, as well as providing information for new mines proposed by the uranium mining industry. This presentation will provide principal results of the three technical reports issued, and elements of the proposed EPA program for uranium mining TENORM.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has previously issued reports on the uranium mining industry in response to congressional mandates and programmatic needs [1, 2, 3]. During the period 1989 to 1993, EPA worked on a draft scoping report, now unavailable, which compiled information on diffuse sources of TENORM in several industries, including uranium mining, though it was ultimately decided that a final report would not be issued. Following a review of EPA's guidance for TENORM by the National Academy of Sciences [4], EPA's response to the NAS study [5], and discussions with EPA's Science Advisory Board (SAB),

¹ TENORM is defined in this paper as: *Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing.* "Technologically enhanced" means that the radiological, physical, and chemical properties of the radioactive material have been altered by having been processed, or beneficiated, or disturbed in a way that increases the potential for human and/or environmental exposures. This definition further amplifies the need to include materials which have not been modified by human activities, yet have been disturbed in such ways that they can be misused by humans, or affect the environment. It does not include a reference to Atomic Energy Act (AEA) materials as the definitions of byproduct material are changing as a result of passage of the Energy Policy of 2005.

EPA's Radiation Protection Division decided that a further review of the current hazards associated with uranium mining TENORM was warranted.

The SAB [6] agreed with EPA's intent to make TENORM documents useful to a broad audience, but also recommended that the whole life cycle of a TENORM source, in this case uranium extraction, be considered beyond regulatory or inter-agency considerations, and that the impacts of non-radiological contaminants also be examined in the Agency's technical reports. In addition to most sources of TENORM, EPA has authorities for environmental standard setting under the Uranium Mill Tailings Radiation Control Act, cleanup of hazardous waste sites which currently include some former uranium mines, and assistance to Native Americans that has included environmental reviews of proposed *in situ* leach (ISL) facilities license applications.

The Agency plans to issue its technical report on uranium mining TENORM in two volumes as described below, and has separately published a digital uranium location database (ULD). The first volume was issued in 2006 with the second to follow in 2007, and drafts of both volumes were peer reviewed. Based on reviewers' comments received on the draft reports as well as meetings with stakeholders to discuss a proposed strategy for its future efforts, the Agency will make a determination on what further steps may be necessary for the purpose of radiation protection from this source of waste material. The specific wastes of EPA concern from this report and study are from conventional open-pit and underground uranium mines, and include overburden, unreclaimed subeconomic ores (protore), waste rock, core hole and drill cuttings, mine and pit (or pit lake) water. Much of the discussion and field data in this paper is derived from the three current EPA reports.

MINING AND RECLAMATION BACKGROUND REPORT

In 2006, EPA issued its *Technical Report on Technologically Enhanced Naturally Occurring Radioactive Materials From Uranium Mining; Volume I: Mining And Reclamation Background* [7]. This document examines the occurrence of uranium in its natural settings in the United States, its industrial uses, and the methods employed over the last century to extract it from ore deposits. In addition, it explores the nature of solid and liquid wastes generated by the extraction methods, and the various reclamation and remediation methods used to restore the extraction site. It also provides some limited information on uranium milling and ISL operations and waste generated by those processes, even though they are considered to be byproduct materials, not TENORM, under the AEA. As well, information is provided on the regulatory agencies responsible for oversight of uranium mining and extraction operations. Rather than summarize the uranium production history, mining and reclamation technology discussions of that report, the discussion below will highlight the principal findings on uranium mine TENORM wastes from that report.

Most uranium mining in the United States has taken place in the Colorado Plateau region including the states of Utah, Colorado, New Mexico, and Arizona, though more than a dozen states have hosted uranium mining operations. Some mines were focused on extraction of just uranium minerals, whereas many mines or mineral prospects were established for extraction of other minerals (such as copper, gold, silver, phosphate, molybdenum, etc.), but uranium was also associated with the deposit. Depending upon economics of the time, the uranium may have been processed and extracted, or left as a mine waste

Mining is the mechanical process by which mineral ores are extracted from the earth. The term ore implies economic viability in which the value of the metal extracted from the host rock is worth more than the total costs of extraction and site restoration. Protore is mined uranium ore that is not rich enough to meet the market demand and price. This subeconomic ore is often stockpiled at the mine site for future exploitation under the appropriate economic or market demand conditions, but if those conditions do not develop, it may be left as a waste. Overburden is another significant waste material that is classified as TENORM from uranium mining. Overburden overlies the uranium ore body, but is not necessarily enriched in uranium as is protore. Other mine wastes which could be classified as TENORM include waste rock (which is rock void of uranium ore which may have been set aside as waste after removal of top-soil, overburden and uranium ore or veins), drill core and cuttings, and mine and pit (or pit lake) water.

Uranium mining through most of the 20th century was dominated by what are termed conventional methods: open-pit mining is employed for ore deposits that are located at or near the surface, while underground mining is used to extract ore from deeper deposits. The early small mining endeavors generated small quantities of waste typically discarded within a few feet to hundreds of feet (100 meters or more) of the mine opening or pit. Generally, tens to hundreds of acres (or hectares) may be covered by overburden and waste rock at surface mining sites. This study found that the surface area affected by major underground mining activities generally involves less than about 50 acres (20 hectares). Conventional mines, many now abandoned, are scattered over wide areas of the West as can be seen in Figure 1.

The volume of waste produced by surface, open-pit mining is a factor of approximately 45 greater than from underground mining, based on their respective averages. Thus, the amount of overburden generated from open-pit mines far exceeds that of underground mines. The U.S. Geological Survey estimated for EPA [8] that the total amount of waste rock generated by the approximately 4,000 conventional mines in its data files is between one billion and nine billion metric tons of waste, with a likely estimate of three billion metric tons. The characteristics of overburden and waste rock from conventional mines depend on the geology of the zone where the ore was originally mined, and how the waste was subsequently treated. Overburden and waste rock can include huge boulders that may have been broken down with explosives and heavy machinery into particles as small as clay size.

Increased use of ISL as an “unconventional”, though now relatively common, mining method, has significantly reduced the volume of solid waste generated. The solid waste from ISL is regulated by the NRC or its Agreement States as byproduct material, not TENORM, and consists of: (1) soil and weathered bedrock material, (2) waste from drilling of injection and production wells, and (3) solids precipitated during storage and processing of fluids in holding ponds. EPA found that the total areal extent of an ISL operation may be large, covering from 200 to more than 6,000 acres (81 to 2,430 hectares), depending on how drill holes are situated, and how extensive evaporation ponds are, though the surface facilities themselves may take up only a small part of the total acreage [9]. Available data are insufficient to estimate the total amount of solid and liquid wastes generated by existing and previous ISL operations.

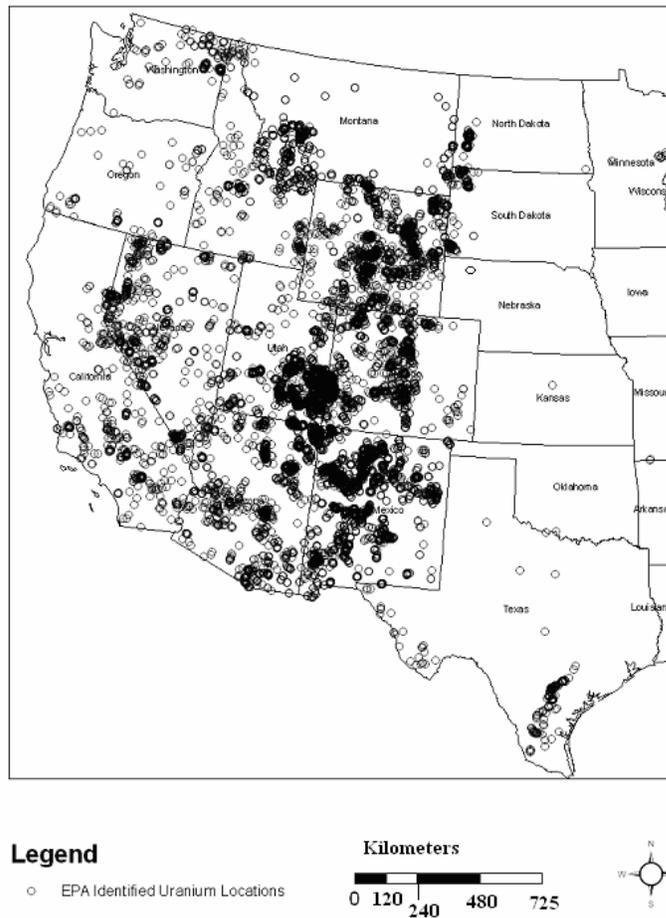


Figure 1. EPA Uranium Location Database uranium locations in the western U.S.
A discussion of this EPA database [10] is found in the text further below]

Radiation and hazardous materials studies from mine reclamation assessments indicate that material identified as “waste” or “overburden” varies widely in radium-226 activity, but that for most waste piles dominated by overburden material, measurements higher than 20 pCi/g (0.74 Bq/g) are unusual. Protore, on the other hand, can be considerably higher in radium-226 activity, with most material in the range of 30–600 pCi/g (about 1–22 Bq/g) [9]. As a point of comparison, information on radionuclides present in ISL operation wastewater ponds is very limited. Liquid wastes from those operations, regulated by the NRC or its Agreement States, have some residual uranium and radium-226 activities that range from background levels (<2 pCi/L) to concentrations as high as 3,000 pCi/L (111 Bq/L). Solid wastes from ISL operations can have several hundred ppm uranium and 300–3,000 pCi/g radium-226 (about 11–111 Bq/g) [11].

Radon measurements in some abandoned underground mines where mechanical ventilation has

ceased are quite high, and pose risks for prolonged human exposure to the public or workers during recreational visits, exploration of old workings for geologic purposes, or reclamation activities. As an example, radon readings by alpha track canisters installed at underground mine portals of the Ross Adams uranium mine in Alaska measured from 212 pCi/L to 540 pCi/L (about 8 to 20 Bq/L) [12]. Unlike barren or low-activity waste rock, waste rock and protore piles with elevated activity not only form more radon, but in many districts they release a great deal of that radon to pore spaces, and the radon is free to migrate.

Radon flux rates from overburden are difficult to characterize because of the rock's diverse physical forms and matrices, and diverse emplacement and disposal methods. Field measurements indicate that average radon flux rates vary from about 2–60 pCi/m²s (about 0.07–2 Bq/m²s) for overburden materials to as high as a few hundred pCi/m²s (> about 7 Bq/m²s) for low-grade ore materials [13, 14]. The broad range of radon flux rates is due, in part, to varying radium concentrations (the parent radionuclide) found in protore that is at times disposed of with overburden. Radon flux rates much higher than these have been reported for undisturbed natural rock outcrops adjacent to uranium extraction operations.

Elevated gamma radiation is always found at uranium mine sites. The primary contributors to gamma exposure are the decay products of radium; the higher the radium present, the higher the ultimate gamma exposure rate. Radium content is also roughly proportional to uranium content in raw mine materials. A review of abandoned mine reclamation studies [7—see Appendix V] examined found exposure rates associated with ambient background levels range from 10 to 85 µR/hr, averaging about 20 µR/hr including background. Protore exposure rates range from 80 to 1,250 µR/hr, with an average value estimated at 350 µR/hr.

A number of heavy metals may occur in association with uranium deposits and wastes from uranium mining. Heavy metals on site, particularly arsenic, can be of concern, and can pose serious risks if they migrate to groundwater. Waters affected by uranium mining may be on, adjacent to, or at some distance from a mine or mines. Uranium and thorium, and radium to a lesser extent, can be mobilized by either acidic or alkaline solutions. Pyrite and other sulfur-bearing minerals are key determinants as to whether acid mine drainage occurs.

Mining reclamation is the act of returning a mine to a long-term stable condition, or to its original contour, to ensure the safe reuse of the site by both current and future generations. When possible, a reclamation plan aims to return the affected areas to previously existing environmental conditions. Differing views as to what is an acceptable environmental condition for reclaimed mining sites explain the varying regulatory requirements for uranium mining sites. The existence of bonding requirements and/or financial guarantees in the cases where private parties are involved in the mine may also play an important role in determining the extent of reclamation. Extraction facilities licensed by the NRC or its Agreement States are required to have bonds sufficient to allow a third party to reclaim the property should the company holding the site fail. Additionally, regulatory requirements affect selected reclamation techniques, as some techniques may be adequate to meet less stringent requirements, but will not be suitable for more restrictive requirements. In some cases, the remoteness and aridity of a site and reduced risk for human exposure may affect decisions on whether a site is in need of reclamation, or the extent to which it is reclaimed, if at all.

Data from a Department of Energy/Energy Information Administration study [15] reveal that the costs of reclamation without site monitoring for 21 mines ranged from a low of \$2,337/hectare of disturbance to a high of \$269,531/hectare of disturbance. The average total estimated cost is \$13.9 million per mine. Many smaller mines less than 25 acres (10 hectares), which may constitute the majority of currently unreclaimed mine-scarred lands, especially in arid regions, may require remediation costs on the order of \$45,000 or less [16]. This cost would be incurred to bury waste piles back in a pit or underground mine opening, clean up the soil to lower radionuclide and metal levels, and close or armor the mine opening with rock. Remediation actions under CERCLA for spilled ore off-site of a mine can be expensive. U.S. DOE/EIA in 1995 estimated average decommissioning costs for ISL operations were an estimated \$7 million. On the other hand, cleanup in 2005 of 12 sites where ore had spilled off of ore trucks on the haul road between the Midnite Mine and the Dawn Mill in Washington State [17], some 18 miles (29 km) distant, amounted to a cost of approximately \$357,500.

RISK ASSESSMENT REPORT

A second report, *Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) from Uranium Mining: Volume II: Investigation of Potential Health, Geographic, and Environmental Issues of Abandoned Uranium Mines* [18] scheduled to be issued in draft in 2007, for additional public comment, examines, in a general way, the potential radiogenic cancer risks from abandoned uranium mines, as well as environmental and geographical issues associated with those mines. The intent of that report is to generally identify who is most likely to be exposed to uranium, and where the greatest risks may be found.

The definition of a mine leads to problems with determining how many mines really exist. Even a single data set may have different interpretations for what could be considered a mine. Records may indicate multiple mine portals for an underground mine, for example. It is not surprising that different sources have identified different numbers of mines. EPA has compiled a database of locations association with uranium [10], described further below, from the different sources and has identified about 15,000 records, from which redundant records have been removed to the extent possible. The EPA database lists several thousand more locations than any other publicly available data set.

Querying EPA's ULD with software tools from ArcView geographic information system software, using population data from the 2000 census [19], it is estimated that approximately 75 percent of uranium mine and other recorded uranium locations were on federal and Tribal lands. With the large number of locations on federal land, people who use these sites for recreation would most likely have a high potential for exposure to uranium mine wastes. An exception to this would be the uranium mines on Tribal lands, where the Tribal members could potentially receive the greatest exposure.

In conducting risk assessments for this report, information obtained as a result of field studies conducted by EPA as well as literature surveys were utilized. It was concluded that there are several possible scenarios through which humans could be exposed to the various hazards posed by uranium mining TENORM: on-site recreation, homes with contaminated building materials, on-site residents, and near-by (adjacent) residents.

A recreational use could be considered to be one in which the abandoned uranium mine is visited only occasionally by hikers, campers or driven through by all-terrain vehicles. Recreational use also may occur for a site that children may visit if it is located near houses, as, for example, on Tribal lands in the Colorado Plateau. Other exposures might include sites visited by hikers, or swimmers to open-pit mine lakes. Other than the Tribal situations, it is likely people could visit unreclaimed uranium mines for short periods of time, such as two weeks, which is the common maximum time for which the National Park Service issues back-country permits. The primary exposure pathways would be external exposure and drinking contaminated water. Pathways of secondary importance include inhalation of dust, exposure to radon, ingestion of dust on dried or prepared foods, and inadvertent ingestion of soil.

A second scenario that has been known to occur, but whose frequency is unknown, is the situation in which uranium mine waste materials are used for building construction. Although most of the uranium locations are in areas where recreation is the most likely scenario, some uranium locations are near roads, including unimproved dirt roads, where waste material could be accessed. These materials could be transported from a nearby site and used in the construction of houses when other building materials are too difficult or expensive for a home owner to obtain. A third scenario is an individual who lives on the site of a previous uranium mine, while a fourth scenario is someone who lives adjacent to a mine site. Figure 2 provides an example of a house constructed with uranium mine wastes, but whose residents also lived adjacent to a mine and its wastes.

Multiple approaches were taken to understand the risks at these sites. These include reviewing existing data discussed earlier, using geographically based queries of uranium mine and population data, the Superfund Soil Screening Guidance (SSG) approach [20, 21] for chemicals and radionuclides whenever applicable, risk calculations produced for the radionuclides in drinking water regulation [22], and the use of RESRAD BUILD 3.21 [23] for examining building materials. This approach allows for using applicable peer-reviewed methodologies. Using the conservative SSG for radionuclides methodology, some estimates were made of cancer risk for different time periods and different concentrations for natural uranium, Ra-226, and Th-232. Natural uranium was assumed to include U-234, U-235, and U-238, in natural isotopic abundances. U-238 is in secular equilibrium with its short-lived progeny, U-234 is in secular equilibrium with Th-230, while U-235, Ra-226, and Th-232 are in secular equilibrium with their entire decay chains. The slope factors for natural uranium are expressed in terms of pCi of U-238. Arsenic was evaluated using a similar approach, but using the general SSG methodology.



Figure 2. Navajo house adjacent to a uranium mine in northern New Mexico. Radioactive waste rock from uranium mine (now reclaimed) in left foreground of picture was used to build foundation for house shown in upper right. The house was subsequently reconstructed by the Navajo Nation to remove contaminated building materials.

The SSG methodology assumes a linear relationship between a person's incremental cancer risk from exposure to radium (Ra-226), thorium (Th-232), and natural uranium (U-238 + U-235). The incremental cancer risk level of 10^{-6} is usually the baseline level of risk that is acceptable, and 5×10^{-4} is typically at the high end of the range of acceptability. Thus the Soil Screening Levels (SSLs) are evaluated for this range. External exposures are presented here as they produce the greatest risks.

$$\text{Soil Screening Level (SSL)} = \text{TR} / (\text{SFE} * \text{EF}/365 * \text{ED} * \text{ACF} * [\text{ETO} + (\text{ETI} * \text{GSF})])$$

where:

TR	= Target cancer risk (unitless)	variable ($10^{-6} - 5 \times 10^{-4}$)
SFE	= Slope factor for external exposure to soil contaminated to an infinite depth (risk/y per pCi/g)†	8.49×10^{-6} for Ra-226 1.23×10^{-5} for Th-232 2.14×10^{-7} for U-natural
EF	= Exposure frequency (days/year)	variable
ED	= Exposure duration (year); results in risk per total number of days on site	1
ACF	= Area correction factor for smaller sites = 0.9 if area < 1,000 m ²	1
ETO	= Estimated fraction of time outdoors on site	1
ETI	= Estimated time indoors	0
GSF	= Gamma-shielding factor	0

† Includes short- and long-lived decay products, as discussed in preceding section. Slope factors for radionuclides for all exposure pathways are based on U.S. EPA (<http://www.epa.gov/radiation/health/index.html>).

Recreational Exposure Scenario

For a Superfund target risk of 1×10^{-6} for 14 days of exposure and the assumptions stated above, the Ra-226 soil screening level would be ~ 3.1 pCi/g (~ 114 Bq/kg), but for one day of exposure at a 1×10^{-6} target risk, the Ra-226 soil screening level would be ~ 43 pCi/g ($\sim 1,590$ Bq/kg). Exposure to 12.3 pCi/g (454 Bq/kg) of radium, in secular equilibrium with its progeny, for 350 days, would result in a cancer risk of 10^{-4} . Table I illustrates the relationship between radium concentration and risk for different times of exposure.

In developing the recreational scenario, it was conservatively assumed that the exposed individual spends the entire day at the site, with no indoor time—that is, the individual spends all day on the waste material and sleeps in a tent or other light structure that provides no appreciable shielding. Since no time is spent indoors, the indoor part of the equation with the gamma shielding does not come into play.

Multiple additional recreational scenario risk assessments, which may be found in the full report, were conducted evaluating the dose received from soil ingestion, water ingestion, dust inhalation, swimming, and use of all terrain vehicles over uranium mine TENORM wastes, with exposures to uranium, radium, thorium, strontium and arsenic. For the occasional visitor to abandoned mines, the mine wastes typically won't produce much of a radiation risk. However, individuals who visit a site for long periods of time, or frequently, can incur substantial risks.

Table I. Screening Levels for External Exposure to Ra-226.

EXPOSURE FREQUENCY (DAYS)	TARGET CANCER RISK					
	5×10^{-4}	1×10^{-4}	5×10^{-5}	1×10^{-5}	5×10^{-6}	1×10^{-6}
	Concentration of Ra-226 in pCi/g (Bq/kg)					
1	21,485 (794,945)	4,297 (158,989)	2,149 (79,513)	430 (15,910)	215 (7955)	43.0 (1591)
14	1,535 (56,795)	307 (11,359)	153 (5661)	30.7 (1136)	15.3 (566)	3.07 (114)
30	716 (26,492)	143 (5291)	72 (2664)	14.3 (529)	7.2 (266)	1.43 (53)
52	413 (15,281)	83 (3071)	41.3 (1528)	8.3 (307)	4.13 (153)	0.83 (31)
140	153 (5661)	30.7 (1136)	15.3 (566)	3.07 (114)	1.53 (57)	0.307 (11)
350	61.4 (2272)	12.3 (455)	6.14 (227)	1.23 (46)	0.614 (23)	0.123 (5)

Building Material Exposure Scenario

In the Grand Junction, Colorado area, thousands of homes and properties have used uranium mill tailings [1] in the past as a source of construction sand, gravel, and clays. But a number of homes have also been built with materials that have been attributed to “uranium ore” that are not mill tailings. EPA has provided support for identifying buildings on Tribal lands constructed with uranium mine wastes. A specific case of the potential problem on Tribal lands is illustrated by houses with elevated radioactivity found in the Monument Valley area of Utah [24]. In April 2001, EPA razed and removed a building that had been used as a hogan (sacred home) by a Navajo family. The hogan was a small, one-room round structure with a concrete slab for a floor and stucco walls, although the building originally had a dirt floor.

Short-term gamma-ray exposure rates and radon concentrations were measured prior to the demolition of the hogan. Radiation exposures were between 370 $\mu\text{R}/\text{h}$ and 600 $\mu\text{R}/\text{h}$. This is equivalent to doses in air of 325–525 $\mu\text{rad}/\text{h}$ ($\sim 3\text{--}5 \mu\text{Gy}/\text{h}$). (Typical indoor background dose rates are in the range of 1.2 – 16 $\mu\text{rad}/\text{h}$ [12–160 nGy/h]). Several stones in the hogan exhibited levels of 1,000 $\mu\text{R}/\text{h}$ on contact. Short-term indoor radon measurements using multiple methods averaged 50–90 pCi/L (1,850–3,300 Bq/m³) under pseudo-closed conditions. Outdoor exposure rates as high as 75 $\mu\text{R}/\text{h}$ at 3.3 feet (1 m) from the structure were observed. Stones used in the exterior construction produced exposure rates of 500–1,000 $\mu\text{R}/\text{h}$. Inspection of the floor after demolition revealed that uranium ore had been used as aggregate for the concrete. Apparently, the source of the sand and stones in the building material was a nearby uranium mine or an outcrop adjacent to the mine.

Readily available construction materials, including clay, sand, gravel, cobbles, and boulders in above-ground piles from these wastes, make them attractive for houses, stoves, chimneys, and barbecues, and for stucco, cement for log houses, driveways, walkways, and fill dirt. To identify potential gamma and radon exposures over a range of uranium and radium concentrations from contaminated concrete used as building materials for the floor and each wall, we used the RESRAD-BUILD 3.21 computer code [23].

The building we used for our modeling was based on the concrete Monument Valley Navajo hogan. The building modeled had one room with a floor area of 16.4 x 16.4 feet or 269 ft² (5 x 5 m or 25 m²). Each wall is assumed to be 8.2 feet (2.5 m) high, 16.4 feet (5 m) long, with an area of 134 ft² (12.5 m²). Occupancy is assumed to be 70 percent for 365 days a year [25]. Since the calculations were scoping in nature, we used the RESRAD-BUILD default parameters. We assumed that the floors and walls were made of concrete, the radium and uranium concentrations were equal, and the receptor was at a height of 3.28 feet (1 m). However, RESRAD-BUILD calculates the contribution of the floor and the wall, so that the contribution from each part can be separated. The calculations assume no contribution from the soil. The concrete was assumed to be 6 inches (15 cm) thick, with a density of 2.4 g/cm³. Results are presented in doses, which is what RESRAD-BUILD calculates. From the modeling conducted using RESRAD-BUILD, we calculated doses from external exposures to U-238 and Ra-226 in full secular equilibrium with their short-lived progenies.² These doses are listed in Tables II and III

Table II. Doses from 30 years of External Exposure to U-238 in a Navajo Hogan

The dose from the floor is about equal to all of the walls combined.

Activity Concentration pCi/g (Bq/kg)	Dose from Floor mrem (mSv)	Dose from One Wall mrem (mSv)
1 (37)	1.88 (0.02)	0.554 (0.006)
50 (1850)	93.9 (0.9)	27.7 (0.3)
150 (5550)	282 (2.8)	83.1 (0.8)

² This is somewhat different from the way uranium was characterized in the analyses presented in the recreational scenario. In the latter case, all uranium isotopes were assumed to be present in proportion to their natural abundance, and all long-lived progenies except Ra-226 and its decay chain were included, whereas the building scenario analysis addresses only U-238, the dominant isotope, and its short-lived progeny.

Table III. Doses from 30 years of External Exposure to Ra-226 in a Navajo Hogan

The dose from the floor is about equal to all of the walls combined.

Activity Concentration pCi/g (Bq/kg)	Dose from Floor mrem (mSv)	Dose from One Wall mrem (mSv)
1 (37)	139 (1)	40 (0.4)
10 (370)	1394 (14)	401 (4)
20 (740)	2787 (28)	801 (8)

Although U-238 would contribute to the overall radiation exposure, the Ra-226 in the mining waste materials is the more hazardous of the two radionuclides. A concentration of 1 pCi/g (37 Bq/kg) of Ra-226 in the floor is estimated to result in a dose of about 140 mrem (1.4 mSv) during 30 years of external exposure.

URANIUM LOCATION DATABASE

Released in September 2006 as a digital product, EPA compiled multiple data sets into a larger database on uranium mines or mines with uranium, sites explored for uranium, and mills throughout the United States, though concentrating on sites of the western U.S. The compilation was developed to provide a better understanding of the geographic impacts and potential risks posed by uranium mining, and the coincidence with human, cultural, and environmental resources. The focus of EPA's ULD compilation is the western United States. Because most uranium mining occurred in the western United States, and this Agency effort coincided with a Colorado Plateau initiative in the EPA's Region 8 office in Denver, Colorado, the initial database compilation efforts were focused there.

Working cooperatively with the Bureau of Land Management (BLM), Forest Service (FS), EPA regional offices, Navajo Nation, and state agency offices, multiple western state databases have been incorporated into a master database. The U.S. Geological Survey's (USGS) Minerals Availability System/Minerals Industry Location System (MAS/MILS) and Mineral Resources Data System (MRDS) [26] databases are also included (uranium locations identified in the eastern U.S. and Alaska are solely based on these two databases). Even though these national data sets are presented, it is the different state and more local federal databases that make the data in this effort more comprehensive than the previously released national data sets. The data sets include information on the locations of uranium occurrence and extraction sites, but due to resource and other constraints at the time, did not include the reclamation status of those sites.

Efforts were made to eliminate redundant records, and steps were taken to determine the accuracy of the data and their reliability. A master database is included that represents the result of these efforts. However, the individual databases are included separately as well. Because there were numerous sources of data used in this compilation, however, efforts were made to reduce mine duplication and compare with existing data sources for accuracy. This was done, in part, by comparisons with U.S. Geological Survey (USGS) topographic maps at different scales. An effort was made to develop some indication of the reliability of the data, such as the availability

of documentation. The result of this effort produced the master database and composite shapefile that can be used as a layer with geographic information systems (GIS).

Completeness, in the sense of whether or not all uranium deposits are listed in this composite database, can never be fully determined. To better understand database completeness, the database composite was compared to the authoritative source of producing mines for Texas, available from the Texas Railroad Commission (RRC). All of the mines in this source are represented in some fashion in the composite database, therefore the composite appears to be complete in this regard. In fact, the reverse finding, that more records of locations in Texas are present in the composite database than in the RRC database, highlights the fact that the composite contains records that may represent individual mine features, "dogholes," and other features which may not meet the definition of a producing mine, but which could be the site of uranium mining wastes.

Although many of the mine locations appear to be accurate within several hundred meters, the accuracy range represented in the composite database is generally between 0 and 1500 meters for database records compared to mines on USGS topographic maps. While this range is broad, it represents an average discrepancy between coordinate information available in the database and the USGS map location where the deposit in question may be found. The ends of this range were determined by comparing a small sample of ULD mine records represented on USGS 1:24,000 scale maps that contained the most mines providing a good comparison sample. The USGS mine locations were deemed authoritative since they were identified from 1:24,000 scale maps (or better) and sometimes confirmed and labeled with mine names using local authoritative data when available.

EPA APPROACH TO URANIUM MINING TENORM WASTES

In order to obtain stakeholder views on the next steps to be taken in EPA's uranium mining TENORM program, a proposed approach has been developed which is predicated on internal analyses of the findings of the technical reports, and sectors of the public most potentially impacted by this waste. EPA intends to meet with stakeholder groups during 2007 to focus and evaluate this proposed approach. In line with its overall strategy for TENORM, there are three main objectives: (1) *to further identify and characterize abandoned uranium mine risks*, (2) *reduce risks from contaminated buildings*, and (3) *participate in activities that reduce risks from uranium mines on federal lands*.

With respect to EPA efforts to further identify and characterize abandoned uranium mine risks, it is proposed that participating organizations and agencies which contributed to the existing ULD report be asked to provide new information. The information would be for the purpose of compiling a new data set on mines and locations which had been closed or remediated. This would help to better characterize the extent of wastes that still posed potential hazards to members of the public or the environment. EPA would also, to the extent possible with existing resources, provide assistance to EPA regions, federal, state, Tribal agencies as requested to conduct additional health risk assessments. Concerning ecological assessment, it is proposed that additional data would be collected, and that assistance would be provided to others requesting help in this area.

Recognizing that there may be numerous houses and other structures built using uranium mine wastes, and that radiation exposures to members of the public may be significant, an important part of the EPA effort will be to reduce risks from contaminated buildings. Experience suggests that these buildings are most likely to be found on Tribal lands. EPA efforts to provide assistance to Tribes as a part of its trust responsibilities would be conducted in coordination with EPA's regional offices. In addition to public education on the risks of using these TENORM wastes for building materials, other aspects of the program could include hazard assessments, efforts to locate the houses, and identifying means of reconstruction or cleanup.

Given that approximately seventy-five percent of uranium locations identified by EPA are on federal lands, EPA proposes to participate in activities that reduce public exposure risks to these TENORM wastes. EPA provided its ULD database in 2006 to other federal land management and science agencies to create the National Mine Land Inventory [27] which can be used by those agencies for example in assessing impacts and hazards from abandoned mine lands, and for identifying abandoned mine lands for future cleanup. Other parts of EPA's potential approach to alleviating these risks on federal lands is to develop non-Superfund related guidance on when, and to what level to reclaim sites, conducting or assisting in site health and ecological assessments when requested.

CONCLUSION

EPA's effort to characterize uranium mining TENORM wastes and their associated hazards is nearing completion. The Agency published in 2006 a technical report on the mining and reclamation background of this material including its physical, chemical, and radiological characteristics, as well as a geographic database on locations with uranium principally in the western U.S. A third technical report which should be finalized in 2007, examines, in a general way, the potential radiogenic cancer risks from abandoned uranium mines, as well as environmental and geographical issues associated with those mines. The intent of these reports is to generally characterize the nature of these materials, how the wastes are created and sites cleaned up, provide an understanding of the governmental agencies responsible for regulating the wastes and mining/extraction sites, identify who is most likely to be exposed to these TENORM wastes, and evaluate where the greatest risks may be found.

Based on the results of this work, the Agency has proposed an approach to reduce the risks and exposures associated with uranium mining TENORM. Meetings with stakeholders, addressed principally to those most impacted by these wastes, will examine the proposed approach and be used to determine EPA's likely next steps.

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